

C³ Demonstration Plan

Seattle Snowmass Summer Meeting 2022

Faya Wang

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Introduction Staged Approach

- C³ technology: Modularized linac technology based on liquid N₂ cooled c-band cavity.
- Each cryomodule (CM) is about 9 m long and has 4 rafts.
- Each raft has 2 accelerator structures and one quadrupole magnet.
- Each CM can be driven by 4 X 50MW klystrons and can reach up to 0.8 GeV.

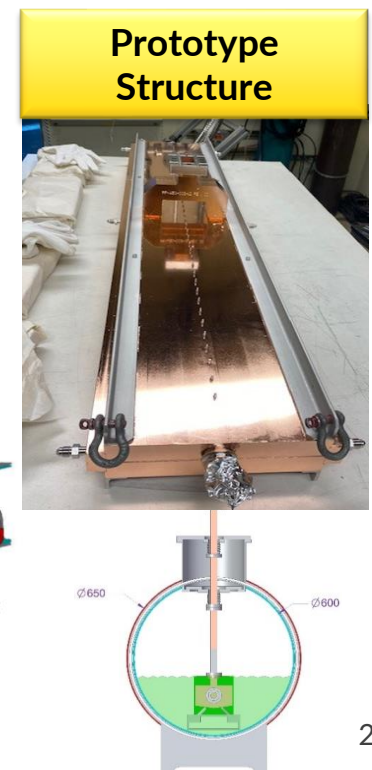
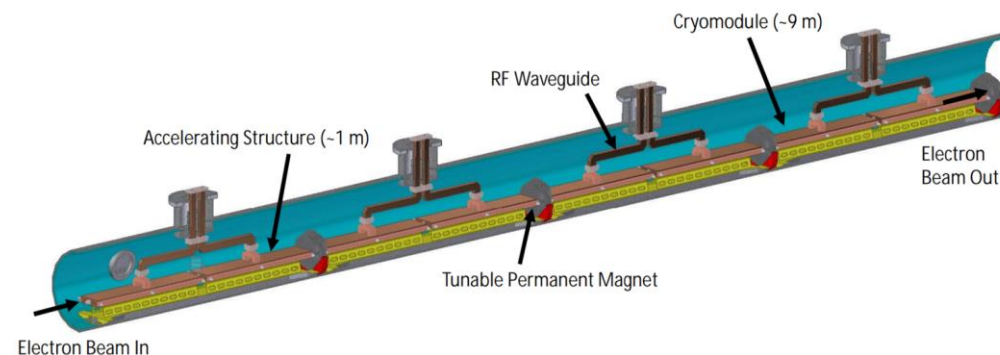
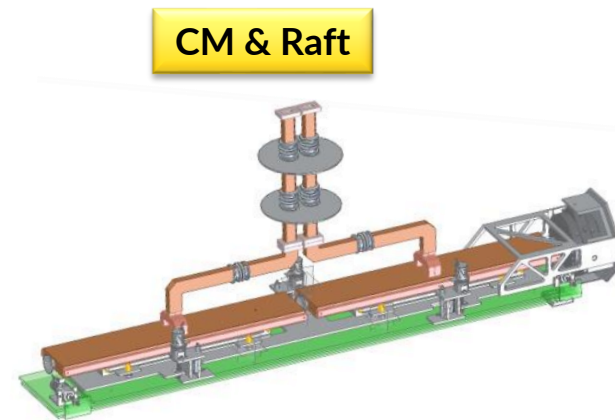
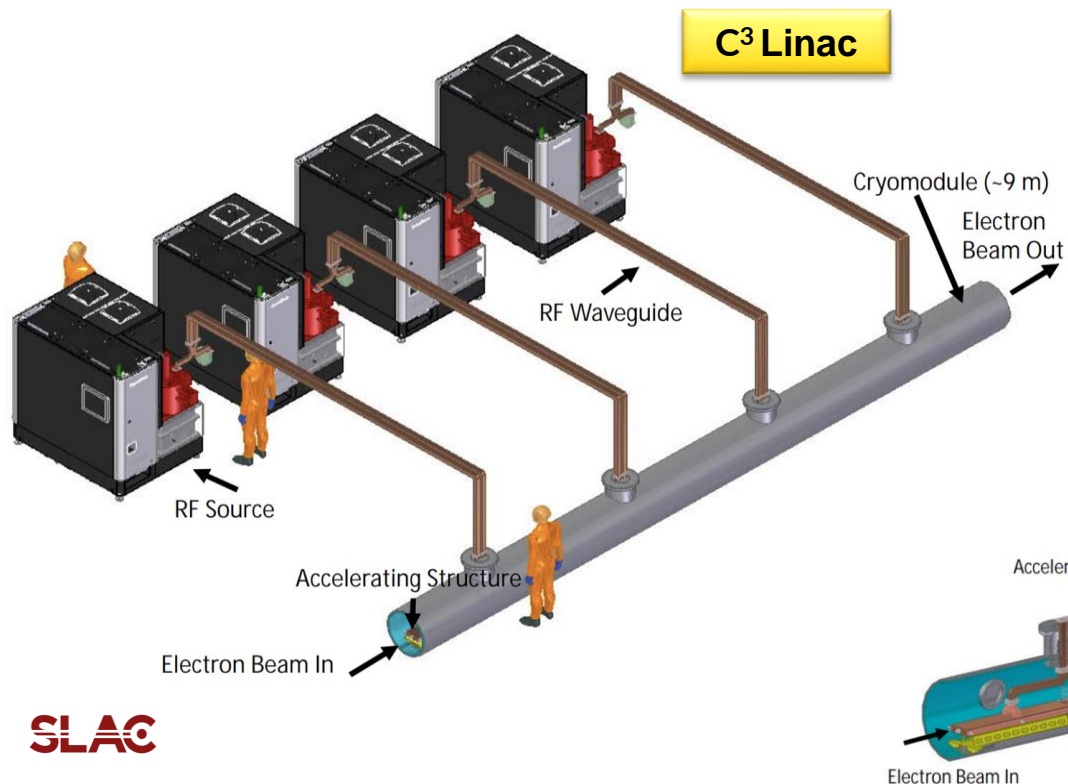


Table of Parameters – 250/550 GeV

Collider	CLIC	ILC	C ³	C ³
CM Energy [GeV]	380	250 (500)	250	550
Luminosity [$\times 10^{34}$]	1.5	1.35	1.3	2.4
Loaded Gradient [MeV/m]	72	31.5	70	120
Geometry Gradient [MeV/m]	57	21	63	108
Length [km]	11.4	20.5 (31)	8	8
Num. Bunches per Train	352	1312	133	75
Train Rep. Rate [Hz]	50	5	120	120
Bunch Spacing [ns]	0.5	369	5.26	3.5
Bunch Charge [nC]	0.83	3.2	1	1
Crossing Angle [rad]	0.0165	0.014	0.014	0.014
Site Power [MW]	168	125	~150	~175
Design Maturity	CDR	TDR	pre-CDR	pre-CDR

Ref: M. Bai et al, SLAC-PUB-17629

Table of Parameters – 250/550 GeV

- Main linac total cryogenic heat load
 - 9 MW (C³250, C³550-8km) – 0.4 W/cm² on structure
 - 13.4 MW C³550-7km without Pulse compressor - 0.6 W/cm² on structure

Gradient (MV/m)	Power diss. (W)	rf flat top (ns)	Pulse compr.	Comments	Power/area (W/cm ²)	ΔT Cu-bulk to LN ₂ (K)
70	2500	700	N	C ³ -250	0.393	2.3
120	2500	250	N	C ³ -550	0.393	2.3
155	3900	250	N	C ³ -550 in 7 km	0.614	2.5
120	1650	250	Y	C ³ -550	0.259	2.1

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Design Study C³-250-550 GeV LC at the next P5!

Minimum requirement for Demonstration:

- **Demonstrate operation of fully engineered and operational cryomodule**
 - Simultaneous operations of min. 3 cryomodules
 - Demonstrate operation during cryogenic flow equivalent to the main linac
- **Demonstrate beam dynamics**
 - Fully damped-detuned accelerating structures and beam-based alignment
 - Operation with a multi-bunch photo injector
 - Beam diagnostic line
- **Demonstrate full operational gradient 120 MeV/m (and higher > 155 MeV/m) w/ single bunch**
 - Must understand margins for 120 - targeting power for (155 + margin)
 - 18X 50 MW C-band sources - off the shelf units
- **Manufacturability development with industry on rf source, structures and cryomodules.**

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- **3: CM linac scale-up full demonstration for linear collider (LC)**
 - Beam dynamics demonstration: wakefields, alignment, and stability (jitter, vibration, etc) control.
 - Full cryogenic (gas/LN) flow rate at equivalent heat load of LC.

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- **2: CM scale-up minimum demonstration**
 - Beam dynamics: long range wakefields, beam-based alignment
 - Availability with and without beam

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 - Beam acceleration, beam loading, energy stability
 - Initial verification of RF and CM design

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❖ 4 stages – goals & scope & deliverables

- 2028- 2030
 - 3: CM linac scale-up full demonstration for linear collider (LC)
 - Beam dynamics demonstration: wakefields, alignment, and stability (jitter, vibration, etc) control.
 - Full cryogenic (gas/LN) flow rate at equivalent heat load of LC.
- 2026- 2028
 - 2: CM scale-up minimum demonstration
 - Beam dynamics: long range wakefields, beam-based alignment
 - Availability with and without beam
- 2023- 2026
 - 1: CM engineering design study and prototypes
 - Beam acceleration, beam loading, energy stability
 - Initial verification of RF and CM design
- 2022 - 2023
 - 0: Proof of concept for the most critical structure performance parameters

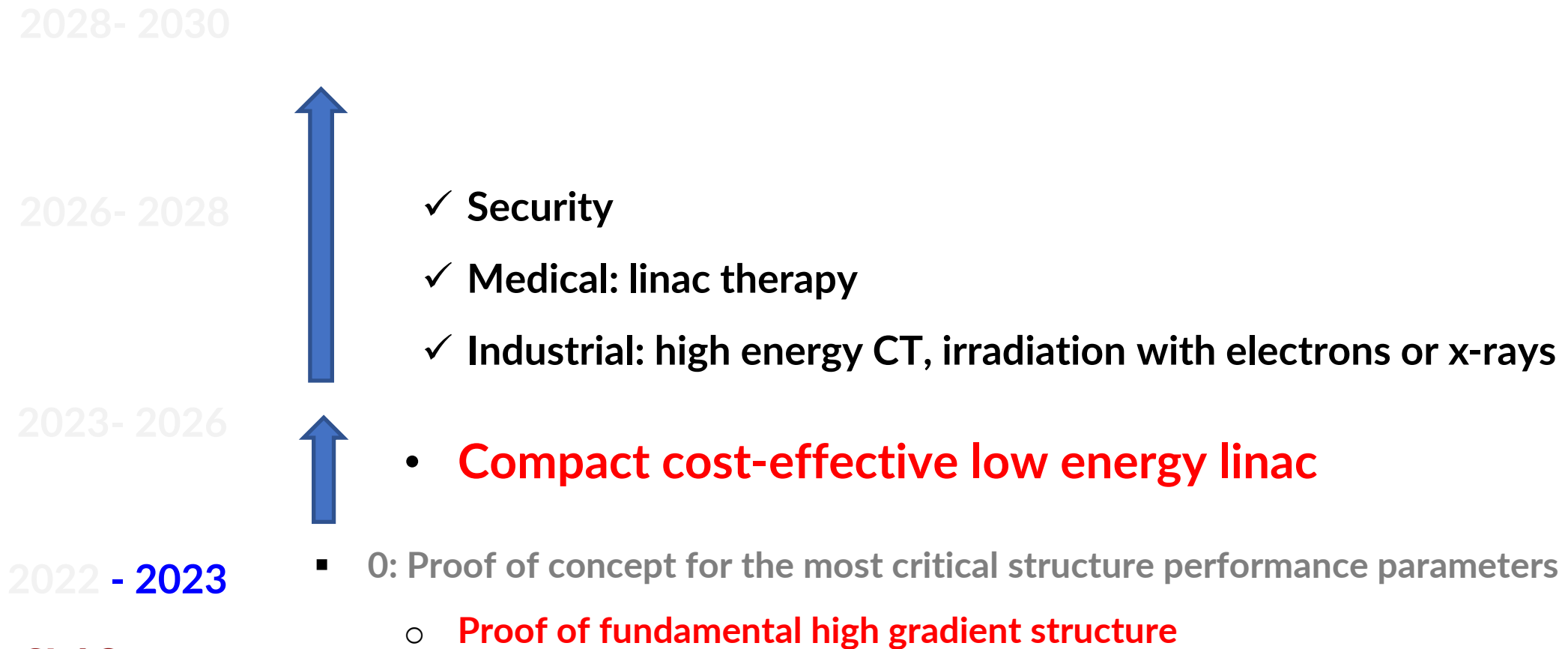
Introduction Staged Approach

❖ 4 stages – goals & approach & deliverables

- 2028- 2030
 - 3: CM linac scale-up full demonstration for linear collider (LC)
 - A linac of 3 cryomodules
 - An injector and beam diagnostic line
 - Cryogenic system for 5.5 L/s LN flow test (9 MW equivalent heat load)
- 2026- 2028
 - 2: CM scale-up minimum demonstration
 - Full dressed single CM (4 rf stations and 8 rf structures)
 - A multi-bunch photo injector and beam diagnostic line
- 2023- 2026
 - 1: CM engineering design study and prototypes
 - Full dressed half CM (2 rf stations and 4 rf structures)
 - An injector with thermionic DC
- 2022 - 2023
 - 0: Proof of concept for the most critical structure performance parameters
 - Regular structure baseline high power test

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❖ 4 stages – goals & scope & **deliverables**



Introduction Staged Approach

❖ 4 stages – goals & scope & **deliverables**

2028- 2030

2026- 2028

2023- 2026

2022 - 2023



- ✓ Medical: VHEE therapy, linac based proton therapy
- ✓ Compact high energy (100s keV to 1MeV) Compton source
- ✓ Lower energy injector for booster ring
- ✓ High brightness injector feasibility

- **Compact high energy linac**

- 1: CM engineering design study and prototypes
 - **A half CM with 2x50MW klystrons – 0.4 GeV over 5 meters**

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❖ 4 stages – goals & scope & **deliverables**

2028- 2030

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2022 - 2023



- ✓ Energy booster with existing facilities like LCLS-X
- ✓ Compact light sources like FEL.

- **Compact high energy linac module**

- 2: CM scale-up minimum demonstration

- **A single CM linac with 4x50 MW klystrons of ~ 0.8 GeV over 9 meters**

Introduction Staged Approach

❖ 4 stages – goals & scope & **deliverables**

2028- 2030

2026- 2028

2023- 2026

2022 - 2023



- ✓ Positron generator
- ✓ Advanced accelerator concept study like PWFA
- ✓ Full energy linac injector for storage ring.

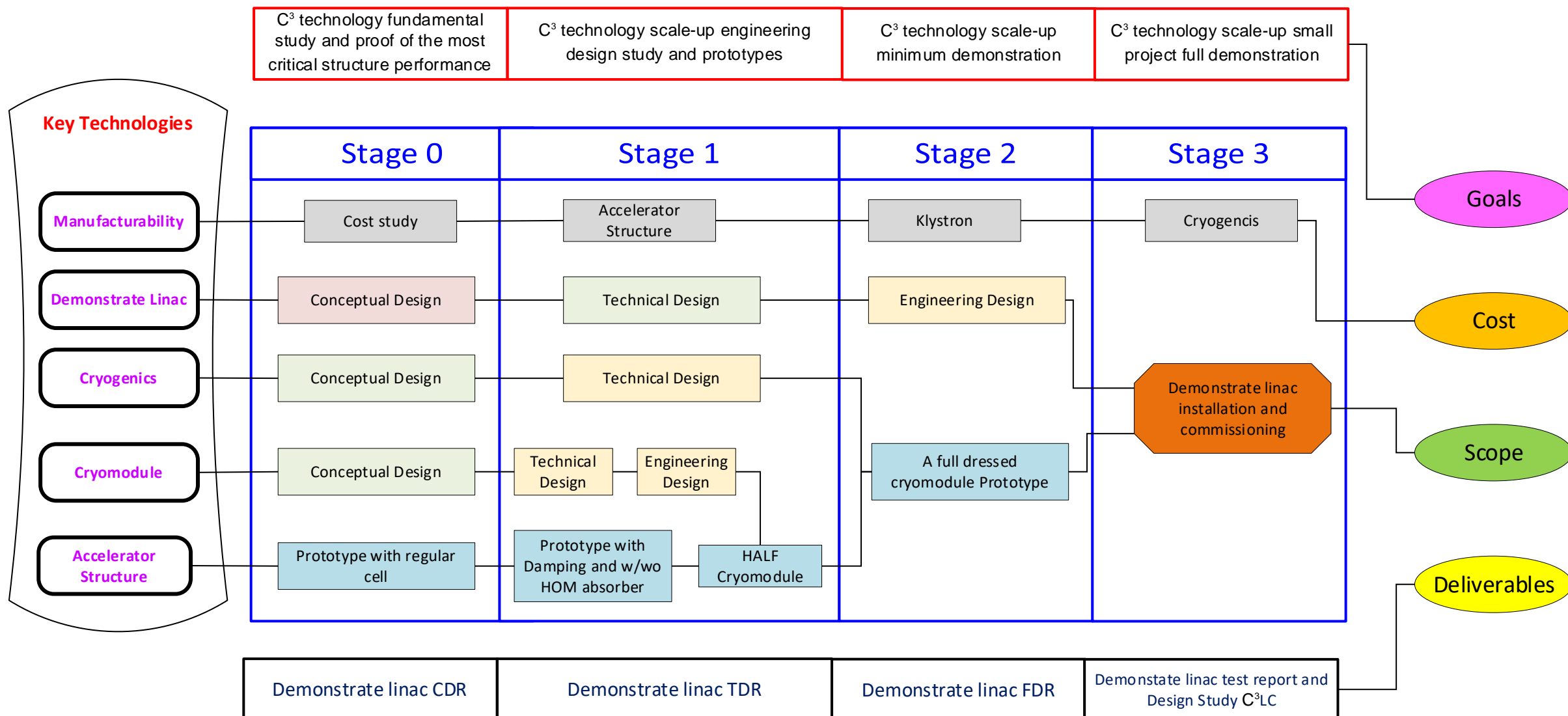
- **Compact high energy full linac**

- 3: **CM linac scale-up full demonstration for linear collider (LC)**

- **A C³ full linac of 3 CMs ~ 3 GeV over about 30+ meters**



Demo R&D Plan Summary





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❑ In Next 4 Years

- ✓ Finish few prototype structures (with and without damping) test
- ✓ Accomplish C3 technology scale-up engineering design minimum demonstration
 - Half cryomodule demonstration with high current/charge beam
 - Built two high power c-band test stands
- ✓ Initiates industrial engagement for manufacturability development

❑ Possible Spin-offs

- ✓ Compact medical and industrial linac.
- ✓ Low emittance NC photo injector development
- ✓ Energy booster linac for LCLS-X
- ✓ Compact full energy linac injector for Synchrotron light source

Questions?